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PATENT APPLICATION

FOR

ASSEMBLY FOR STACKING OPTICAL FIBERS IN AN ALIGNED TWO DIMENSIONAL ARRAY

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INTELLECTUAL PROPERTY LAW

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ASSEMBLY FOR STACKING OPTICAL FIBERS IN AN ALIGNED TWO DIMENSIONAL ARRAY

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FIELD OF THE INVENTION

The present invention relates to an assembly for stacking optical fibers with their ends in an aligned two-dimensional array. The stackup assembly is particularly well suited to the mass termination of optical fiber cables, fiber bundles or optical fiber ribbons. The inventive assembly can be implemented as a termination block or as a connector.

BACKGROUND OF THE INVENTION

Assemblies for arranging optical fibers with their ends in precisely aligned arrays have become increasingly important in optical fiber communication systems. High capacity bundles and ribbons carry numerous small fibers with tiny light-guiding cores that must be precisely aligned for interconnection with transmitters, receivers, other fibers or optical processing devices. The fibers to be aligned can be individual fibers, bundled fibers or fibers from ribbons. The ends are typically stripped of protective polymer and cleaved for insertion into the assembly. The assembly protects the fragile exposed ends, provides strain relief and provides ferrules to facilitate alignment.

Such assemblies are typically in the form of termination blocks or connectors. Termination blocks are generally used for permanent interconnection. Connectors are similar assemblies with the added feature of removability from the device into which the connector is inserted.

Ferrules for facilitating alignment have taken a variety of forms. Traditionally they were hollow metal cylinders that forced like-diameter or even unequal diameter fibers into axial alignment for minimum loss of transmitted light.

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In terminating arrays of rows of optical fibers, it is cost and time prohibitive to align each fiber with its mating optical connection by a single ferrule. Thus techniques have been developed to mass terminate optical fibers, including techniques of stacking, generally referred to as "stackup".

U.S. Pat. No. 5,620,634, entitled METHOD OF MAKING FIBER WAVEGUIDE CONNECTORS, discloses a typical prior art array of V groove plates facing one another. The '634 patent offered the use of alignment pins during a precision molding process. U.S. Pat. No. 5,519,798, entitled OPTICAL FIBER CONNECTOR INCLUDING V-GROOVED/PIN ALIGNMENT MEANS, described pins and spring clip to achieve alignment with a single layer of V groove plates facing one another. Pins and spring clips are also the method of alignment in U.S. Pat. No. 4,818,058, entitled OPTICAL CONNECTOR. And, pins combined with a compensation method for "the inherent shrinkage of plastic" were used in a similar prior art structure in U.S. Pat. No. 5,603,870, entitled OPTICAL FIBER CONNECTOR TECHNIQUES.

These methods incorporate registration devices, generally made of a stiff substrate material such as silicon or ceramic, that encase the rows of fibers in "V" shaped serrated structures on two sides of each fiber ("above" and "below" the fiber). Some of these termination devices have been made of plastic materials through molding processes. Unfortunately it has proven very difficult to achieve precision matching of the molded V grooves for holding individual fibers on both sides, particularly in the case of a multiple layer stackup. This difficulty is due to the problem of achieving registration of the two mold surfaces that stamp the two sides of a plate with grooves. Typically in a production environment, the surface stamping of one side loses the required precision of registration with respect to the surface stamping of the other side. While some of the arrangements have achieved reasonable reliability, none have been well suited to low cost mass manufacture.

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SUMMARY OF THE INVENTION

In accordance with the invention, an assembly for stacking optical fibers in a two dimensional array comprises a plurality of ferrule plates, each plate having a pair of sides. One side of the plate has a plurality of grooves for receiving the fibers, and the other side is flat. Fibers having terminated ends are disposed in the grooves. The plates are aligned and stacked to hold the individual fibers between a groove on one plate and the flat surface of an adjacent plate. Alignment features, such as holes and pins, can facilitate plate alignment. The plates and fibers are secured in aligned position as by epoxy bonding, and the fiber ends are planarized, as by polishing. The assembly disclosed here is especially advantageous for mass termination of fiber optic cables and for interfacing to active devices.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages, nature and various additional features of the invention will appear more fully upon consideration of the illustrative embodiments now to be described in detail in connection with the accompanying drawings. In the drawings:

Fig. 1 schematically illustrates a first embodiment of a stack-up assembly in accordance with the invention;

Fig. 2 is a perspective view of an advantageous form of the Fig. 1 embodiment;

Fig. 2A is an exploded view of the Fig. 2 assembly;

Fig. 3 is a perspective view of a mold set useful in making the ferrule plates used in the embodiment of Fig. 2 ;

Fig. 4 is an exploded view of a second form of the Fig. 1 embodiment;

Fig. 5 schematically illustrates a second embodiment of a stack-up assembly in accordance with the invention;

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Fig. 5A is an exploded view of an advantageous form of the Fig. 5 embodiment; and

Figs. 6, 6A, 6B and 6C are perspective views illustrating an advantageous way to make the ferrule plates used in the embodiment of Fig. 5A.

It is to be understood that the drawings are for the purpose of illustrating the concepts of the invention and are not to scale.

DETAILED DESCRIPTION

Referring to the drawings, Fig. 1 schematically illustrates a first embodiment of a stackup assembly **10** comprising a plurality of "single sided" ferrule plates **12**. The term single sided here refers to the placement of a plurality of fiber aligning grooves **13** on only one side of each plate **12** in the stackup. In this embodiment, the grooves are V-grooves, and the plates are stacked with the V-groove side **14** of each plate adjacent to the flat side **15** of the next succeeding plate. Optical fibers **16** are disposed in the grooves **13** and retained within the grooves by adjacent flat surfaces **15** and appropriate bonding material, such as epoxy **9**. The top plate in the stack **10** need not have grooves and can be a flat lid **17**. Alternatively, the top plate could have grooves (not shown) on the top surface.

The plates **12** and lid **17** are stacked in vertical alignment with their grooves **13** aligned. Advantageously the edges are also aligned. Alignment can be facilitated by alignment holes **18** and alignment pins **19**. The grooves **13** and the alignment holes **18**, for each plate **12**, are advantageously formed by the same molding surface so that alignment of the holes by the pins precisely aligns the grooves in the respective layers.

Fig. 2 illustrates an advantageous embodiment of such a stackup assembly. Fiber ribbons **21** enter between each pair of plates **12** in stackup assembly **10**. Indentations **22** provide space for the unstripped portion of each fiber ribbon **21**.

Fig. 2A is an expanded view of the Fig. 2 embodiment, with the plates **12** shown physically apart for insertion of individual fibers **16.** Individual fibers **16** are stripped from the ribbon **21** and cleaved for location in the V grooves **13**. Because the fibers are sandwiched between V grooves on one side and the flat surface on the other side, the fibers are aligned. Registration pins **19** (only partially shown in Fig. 2A) can be placed in precisely located pin holes **18** in each plate to facilitate vertical stacking and alignment of the plates, and the plurality of layers of optical fibers (shown here as three layers). After the stack assembly is complete, with optical fibers in the grooves and locked in place, fibers are polished against the plate edges in a plane typically normal to the fibers. This step completes the longitudinal registration of the fibers in the 2 D array.

An advantageous process for making the assembly of Figs. 1 and 2 comprises molding the plurality of ferrule plates. In the molding step, a first molding surface moldingly engages the material to be molded to form the major surface **14** having grooves **13**. The major flat surface **15** can be formed by molding with a second molding surface. Alternatively, the flat surface **15** can be preformed, as by machining, and only the grooved surface **14** need be molded. The first molding surface includes a molding pattern to form the grooves and to form registration features for the grooves.

Fig. 3 shows a mold set **30** useful for making the ferrule plates **10** for the embodiment of Fig. 2. Mold set **30** is composed of mold cavity **35** and a mold core **36**. Mold cavity **35** includes a molding surface **31** to mold features to form the edges of the ferrule plate, features **34** to form the grooves, features **32** to form the indentation for the unstripped portion of the fiber ribbon, and features **33** to form the alignment holes.

After providing a plurality of such plates, the assembly is then stacked by disposing optical fibers in the grooves of a plurality of plates and covering the grooved surfaces with the flat surfaces of respective neighboring plates. Finally, the plates and fibers are bonded into an aligned array, and a two dimensional array of fiber ends is formed from the fiber array, as by polishing.

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In a variation of the stackup assembly shown in Fig. 1, alternate layers of plates **12** can be made to different widths and connector pin holes and pins can be provided to facilitate lateral alignment with another stack up assembly. Fig. 4 shows such an assembly. Here, plates **41** are the standard full width, while plate **42** is narrower. This difference in width allows lateral connector pin **44** to contact lateral alignment grooves **45** on plate **41** and the surfaces **46** of lid **47** on alternate sides of narrow plate **42**.

Fig. 5 schematically illustrates an alternative embodiment of a stackup assembly **50**. In this embodiment, except for an interior pair (**12A** and **12B**), the single-sided ferrule plates **12** are stacked with the groove side **14** of each on the flat side **15** of a succeeding plate. But at least one interior layer of fibers **16** is held in place by the opposing groove surfaces of plates **12A** and **12B**. Because the plates are single sided, the layers of the stackup on either side of the interior plates **12A**, **12B** rest on one flat surface, as discussed above.

Fig. 5A shows a preferred form of the Fig. 5 assembly including arrangements to achieve lateral alignment of the stackup **50** with another stackup (not shown) for use as a connector. Here, lateral alignment pins **44** can be fit into molded grooves **55** between the central pair of plates. Pins **44** project from the front face of the stack (serving as the plug of a connector pair) and may be inserted into corresponding holes in a stack serving as a connector jack (not shown). Indentations **56** are for receiving the unstripped portion of the fiber ribbons. Indentations 52 and matching projections 53 can facilitate alignment of successive plates and reinforce the joint..

It is important to match all of the plates, including the grooves on interior plates **12A, 12B** where the grooved sides face each other. Registering one set of grooves with the adjacent set can be facilitated by making the two plates from an extended symmetrical plate molded in the same form. Fig. 6 illustrates such an extended plate **60**. Here, "extended" means that the molded piece **60** has extra material that can be cut or broken off to create either plate **60A** as shown in Fig. 6A, or plate **60B**, as shown in Fig. 6B. The grooves **13** and common set of alignment holes **18** are simultaneously molded into only one side of an extended piece **60** that can become either of two plates.

After molding, the top or bottom plate is created by separating (cutting or breaking) the extended piece **60** along the appropriate molded relief line **61** or **64**. When making plate **60A**, the extended piece is separated at relief line **61**, and part **63** is discarded. When making plate **60B**, the extended piece is separated at relief line **64**, and part **65** is discarded. The two resulting plates have grooves **13** on one side and a flat surface on the other side, as before. Because the grooves **13** and corresponding alignment holes **18** are molded by the same molding surface and are common to both plates, registration can be held to a tight tolerance. Fig. 6C shows the orientation of plates **60A** and **60B** for final assembly.

It can now be seen that the invention relates to an assembly for stacking and retaining a plurality of optical fibers with their ends aligned in a two dimensional array. The assembly comprises a first plurality of ferrule plates, each ferrule plate having a pair of parallel major surfaces forming a pair of respective sides, one of the sides comprising a plurality of grooves for receiving optical fibers and the other side comprising a substantially flat surface. A plurality of optical fiber having terminated ends are disposed in the parallel grooves. The ferrule plates are stacked with the groove side of each ferrule plate adjacent a flat side of an adjacent plate locking the fibers within the grooves of the groove side. The stacked ferrule plates and fibers are secured to maintain alignment of the fiber ends, and the fiber ends are substantially aligned in a plane.

The invention may now be more clearly understood by the following specific example:

Example:

A ferrule plate having nominal dimensions of 7 mm width by 7.5 mm length and .74 mm thickness is formed by molding, using either a thermoplastic or thermoset compound. To be suitable for this application, a compound requires the ability for precise feature replication and dimensional stability over time. An appropriate thermoplastic compound is a polyphenylene sulfide filled with mineral and / or glass particles, such as Fortron PPS 8670A61 from Ticona. The forming is done in a two-part, separable, hardened steel mold, where the features used to form the grooves and stacking alignment holes are fixed within one half of the mold.

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A ferrule plate includes an array of 12 V-grooves 2.5 mm long spaced .250 mm apart. The approximately 70° included angle and .16 mm depth of each groove are sized such that the centerline of a .125 mm diameter fiber laying in the groove is approximately 53 μm below the ferrule plate's flat surface adjacent to the grooves. A second ferrule plate stacked with its flat surface contacting the fiber array will thus be spaced approximately 10 μm apart from the first plate's surface. A multiple-row stack thus positions the fiber rows .750 mm apart, and the fiber ends are thus aligned in a planar array of about 250 micrometers (0.250 millimeters) x 750 micrometers (0.750 millimeters). The stack alignment holes are .7 mm in diameter and perpendicular to the major surfaces. Pins with a slight interference fit are pressed into them to keep the stack layers in accurate lateral registration. An epoxy, such as Epotek 353ND, is used to permanently bond the plates and fibers together, and the protruding fiber ends are polished smooth and flush with the flat ferrule end face.

It is understood that the above-described embodiments are illustrative of only a few of the many possible specific embodiments, which can represent applications of the invention. Numerous and varied other arrangements can be made by those skilled in the art without departing from the spirit and scope of the invention.

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